

**Memorandum**

|  |  |  |
| --- | --- | --- |
| **From:**  | Dave Dilks  | **Date:** April 1, 2016 **Project:** SRRTTF  |
| **To:**  | Spokane River Regional Toxics Task Force  |   |

**SUBJECT: DRAFT, PRELIMINARY NUMBERS: Magnitude of Sources and Pathways of PCBs in the Spokane River Watershed**

# Summary

The Spokane River Regional Toxics Task Force (SRRTTF) is developing a comprehensive plan to reduce polychlorinated biphenyls (PCBs) in the Spokane River. Development of the comprehensive plan will benefit from an understanding of the sources and pathways of PCBs in the Spokane River watershed, allowing the plan to target control of the most important sources and pathways. A prior memorandum (LimnoTech, 2015) described potential sources and transport mechanisms affecting PCBs in the Spokane River and its contributing watershed. This memorandum quantifies the magnitude of those sources and pathways to the extent possible, using site-specific data when available and literature sources otherwise. Because to the extensive reliance on literature values, many estimates are accurate only to an order of magnitude. Although uncertain, these estimates are still worthwhile, as distinguishing sources and pathways as “likely significant” or “relatively unimportant” will be valuable in developing the comprehensive plan.

Legacy PCBs in buildings (e.g. small capacitors, caulks) and legacy soil contamination are estimated to be the largest sources of PCBs in the watershed. Cumulative loading across all wastewater treatment plants, contaminated groundwater, and stormwater/combined sewer overflows are estimated to be the primary delivery mechanisms of PCBs to the Spokane River. PCB loading from Lake Coeur d’Alene and tributaries are of similar magnitude to these other primary delivery mechanisms, but this is due to a very large volume of flow at a low concentration. Insufficient data exists to made credible estimates of the magnitude of most transport pathways between the above sources and delivery mechanisms.

# Introduction

The SRRTTF is developing a comprehensive plan to reduce PCBs in the Spokane River, designed to identify specific management actions that can be taken to control PCB loads to the river. Work on the comprehensive plan is being conducted through five tasks:

1. Develop Inventory of PCB Sources and Pathways
2. Evaluate Control Actions to address PCB Sources and Pathways
3. Attain Consensus on Alternatives to Be Included in Plan
4. Develop Comprehensive Plan
5. Project Management and Coordination

A prior memorandum (LimnoTech, 2015), corresponding to the first part of the first task, described potential key sources and transport mechanisms affecting PCBs in the Spokane River watershed. That memorandum showed that PCBs originate from many different sources, and are delivered to the river via many different pathways. Selection of the most appropriate management actions will be facilitated by an understanding to the magnitude of the various sources and pathways. This memorandum quantifies the magnitude of those sources and pathways to the extent possible, using a combination of site-specific data and literature sources. The memorandum is divided into sections of:

* Magnitude of sources of PCBs
* Magnitude of delivery mechanisms of PCBs to the Spokane River
* Magnitude of intermediate transport pathways

# Magnitude of Sources of PCBs

Sources of PCBs are divided into three broad categories, based on refinement of earlier PCB source characterization done for San Francisco Bay (SFEI, 2010) and Spokane (LimnoTech, 2013).

* Legacy sources of PCBs currently present in the Spokane watershed
* Ongoing sources of PCBs continuing to be introduced to the watershed via inadvertent production
* Environmental transport of non-local PCBs into the watershed study area, which may either be legacy or continuing sources

The mass of PCB estimated in each source category is provided in Table 1.

|  |  |
| --- | --- |
| **Source Category** | **PCB Mass**  |
| **Legacy** |  |
| Building sources | 23,000 kg |
| Environmental | 5,500 kg |
| Industrial equipment | x[[1]](#footnote-1) |
| **Ongoing** |  |
| Inadvertent production | 0.86 kg/year |
| **Non-Local Environmental** |  |
| Lake Coeur d’Alene | 0.096 kg/year |
| Atmospheric | Unknown[[2]](#footnote-2) |

**Table 1. Mass of PCB Estimated in each Source Category**

The remainder of this section describes how each of these estimates was determined.

## Legacy Sources

Legacy sources are defined as PCBs that were brought into the Spokane watershed in the past, but are not continuing to be produced. These were produced by Monsanto and marketed as Aroclors which were used in machine oils, transformers, and many other products. LimnoTech (2015) divided legacy sources into categories of:

* Building sources: These sources were sub-categorized as either fixed to the building itself (e.g., paint, caulk), or non-fixed and removable (e.g., light ballasts)
* Environmental: These sources consist of contaminated surface soils, contaminated subsurface soils/groundwater, and in-place aquatic sediments in the Spokane River and Lake Spokane.
* Industrial equipment: These sources consist of PCBs contained in various forms of electrical equipment such as large transformers, and hydraulic equipment.

### Building sources

Building sources are sub-categorized as either fixed to the building itself (e.g., paint, caulk), or non-fixed and removable (e.g. lamp ballasts).

#### Fixed Building Sources

PCBs were commonly used in building sealants such as caulks from the 1950s to the 1970s (Robson et al. 2010), to improve the flexibility of the material, increase the resistance to mechanical erosion, and improve adherence to other building materials (Andersson et al., 2004). As such, building constructed from the 1950s to the 1970s may still contain caulks with elevated levels of PCBs. No Spokane-specific data exists defining the quantity of PCBs still present in fixed building sources. However, many studies have been conducted estimating this magnitude for other communities, and these studies can provide a template for Spokane estimates. The methods used vary in terms of complexity, as demonstrated below. Shanahan et al (2015) used the most rigorous approach, estimating the mass of PCBs present in Chicago-area building sources by:

* Examining the building footprint, age, number of stories for each individual land parcel
* Calculating the volume of all buildings constructed between 1940 and 1979 from the building footprint and height data
* Assuming the mass of sealants per unit building volume from literature sources
* Assuming the PCB concentrations in caulk for buildings built between 1940 and 1979 from literature sources
* Assuming the percentage of buildings constructed from 1940 to 1979 contained PCB sealants from literature sources

Ecology (2011) estimated the quantity of PCBs in building sealants in in the Puget Sound Basin based upon:

* Reviewing the available literature for information on the types and ages of buildings most likely to contain caulking with PCBs.
* Sampling available county assessor’s information to estimate the volume of candidate buildings and develop an inventory of caulking material likely to contain PCBs within the Study Area.
* Reviewing the available literature for data on PCB concentrations in caulking material.
* Applying literature values to estimate the mass of PCBs contained in caulk.

Diamond et al (2011), used a range of calculation methodologies, including providing estimates for PCBs in caulk on a per capita basis, calculated as 5.2 metric ton per capita. Lacking readily available information on volume of structures in the Spokane watershed built during the time of PCB use, the Diamond et al (2011) per capita will be used in conjunction with s Spokane watershed population. Estimated population in census block groups was obtained in GIS data format from the U.S. Census Bureau (<https://www.census.gov/geo/maps-data/data/tiger-data.html>). Population per acre was calculated for each block group, and this information merged with watershed boundary delineations obtained from the Watershed Boundary Dataset (WBD). This results in a population estimate for the contributing watershed of 571,045. This results in an estimate of PCBs in caulk throughout the watershed of 2969 kg.

#### Non-Fixed Building Sources

Non-fixed and removable PCBs are contained in small capacitors in a number of non-fixed building related items, such as appliances and lamp ballasts. No Spokane-specific data are available defining the mass of PCBs in this category, but the method applied by Ecology (2011) to estimate the mass of PCBs contained in small capacitors in the Puget Sound watershed can be applied for Spokane. Ecology (2011) described their approach as follows:

A typical small capacitor unit contains 0.1-0.6 pounds (45 - 270 grams) of PCB oil, with lamp ballasts typically containing about 45 - 70 grams per ballast (EPA, 1982). Globally, one-third of all PCB production may have gone into lamp ballasts (Panero et al., 2005). In 1992 the University of Illinois estimated that 10-25% of U.S. household white goods (major appliances) contained capacitors with PCBs (Panero et al., 2005). Though it is known that many small PCB capacitors were manufactured prior to 1978, estimates of the number still in use vary. EPA (1982) estimated that historically there were 870 million small capacitors in use throughout the U.S. in 1977 in industrial machines and small appliances. EPA (1987) also estimated a 10% annual disposal rate in 1982.

Estimates for PCB lamp ballasts currently in use are an order of magnitude higher than the 1982 EPA estimate for small capacitors. These estimates place the number of ballast units remaining in use nationally between roughly 300 million (U.S. Army, 2001) and 500 million (Missoula County, 2010). In 1998, the EPA cited an unnamed industry source that estimated one billion ballasts were currently in use (EPA, 1998). The EPA (1998) reference suggests that the current number of PCB-containing ballasts in use nationally would be somewhere between 280 million, assuming a mean annual disposal rate of 10% from 1998 to 2010, and 69 million, assuming a mean annual disposal rate of 20% from 1998 to 2010.

Applying annual disposal rates of 10 and 20% to the national estimates and scaling to the Spokane study area by local population yields a range of 1,000 t0 500,000 total small capacitors remaining in use. This information, combined with an assumed PCB concentration of 45 – 75 g PCB per capacitor, results in total PCB mass in the Spokane watershed of 50 – 40,000 kg. Following the approach of Ecology (2011), a midpoint value of 20,000 kg was selected as an estimate.

### Environmental

Environmental sources consist of contaminated surface soils, contaminated subsurface soils/groundwater, and in-place aquatic sediments in the Spokane River and Lake Spokane.

#### Contaminated Surface Soils

Meijer et al (2003) concluded that soil may be one of the largest global PCB repositories, due to deposition from manufacturing, leaching from building materials or landfills, and the application of wastewater treatment plant biosolids. Insufficient site-specific data are available defining PCB concentrations in soils throughout the Spokane River watershed. An estimate of the total stock of PCBs in Spokane-area soils was made following the approach used by Shanahan et al (2015), who estimated the soil PCB mass reservoir in the Chicago area from:

* the amount of urban area
* a literature based soil:air exchange depth of 0.12 m.
* an average PCB concentration in urban soils estimated from 15 cities of 50 ng/g dry weight (from a range of 3−220 ng/g)
* the average bulk density of urban soils

Applying that approach to the Spokane watershed results in an estimate of the PCB mass reservoir of 5,500 kg.

#### Contaminated Sub-Surface Soils

Marti and Maggi (2015) searched Ecology databases for sites that could be contributing PCB contamination to the Spokane River via groundwater, and identified 31 cleanup sites. Soils at 27 of the sites had been analyzed for PCBs using method SW8082, with 23 of these sites having had confirmed releases to soils. Of these 23 sites, 13 have undergone cleanups and received No Further Action (NFA) designation. Contaminated soils were removed at twelve of the sites. On-site containment was used at one site. Of the ten remaining sites with confirmed releases of PCB, six are undergoing cleanups, two are in performance monitoring status, and two are awaiting cleanups. Marti and Maggi (2015) prioritized these sites in terms of: 1) confirmed or suspected release of PCBs to the environment, and 2) site status with regard to cleanup activities. No quantitative information was available defining the total mass of PCBs contained at these sites.

#### River and Lake Sediment

The bottom sediments of the Spokane River and Lake Spokane provide another potential reservoir of PCB contamination. An estimate of the total mass associated with this category was made using data from Ecology (2011), Ecology (2015), and Era-Miller (2014). Separate estimates were made for the Spokane River and Lake Spokane.

Ecology (2011) discussed the general lack of bottom sediments in the Spokane River:

One particular macro characteristic of the Spokane River is the general lack of fine depositional sediments in most of the river. Lake Coeur d’Alene acts as a settling basin for sediments transported in the upper watershed, and there are no tributaries to the river between the outlet of the lake and Latah Creek. Spokane River is essentially a free-stone stream environment. Although the dams break the river into a series of pools, there are few areas of placid water above Lake Spokane. The river velocities are high enough and the sediment load low enough to scour the bed or prevent settling of significant fine particulate matter, even immediately behind the dams. As a result, almost the entire riverbed upstream of Lake Spokane (the largest reservoir) is composed of gravel, cobble, and boulders with the finer sediment reserved for limited locations behind the dams, interstitial spaces within the river bed, isolated shoreline deposits, and certain fluvial bar features.

One notable exception is the narrow band of fine, organic carbon rich sediments found near the Upriver Dam reservoir scour the bed or prevent settling of significant fine particulate matter, even immediately behind the dams. As a result, almost the entire riverbed upstream of Lake Spokane (the largest reservoir) is composed of gravel, cobble, and boulders with the finer sediment reserved for limited locations behind the dams, interstitial spaces within the river bed, isolated shoreline deposits, and certain fluvial bar features. One notable exception is the narrow band of fine, organic carbon rich sediments found near the Upriver Dam reservoir.

In the Spokane River, Ecology (2011) reported surface sediment PCB concentrations above Monroe St. of 6.7 ng/g. Era-Miller (2014) reported PCB concentrations from sediment traps at Upriver Dam of 25.4 to 28.5 ng/g and 13.7 to 17.2 ng/g at Ninemile Dam. Ecology (2015) reported surface sediment PCB concentrations at undetectable levels (detection limit ~10 ng/g) in their reassessment of the Upriver Dam and Donkey Island PCB Sediment Site. It is noted that Ecology (2015) reported higher sediment PCB concentrations at depths beneath the cap installed to remediate the site, but concluded that the cap provided an effective barrier form those PCBs reaching the surface. Assuming that 10% of the river contains PCB contaminated bottom sediments at an average of the observed PCB concentrations (15 ng/g) results in a mass estimate of 0.008 kg.

Ecology (2011) also reported sediment PCB concentrations at two locations in Lake Spokane. Concentrations in the upper 10 cm ranged from 8 to 33 ng/g in the upper portion of the Lake to 28 to 75 ng/g in the lower portion of the lake. Assuming an average PCB concentration of 35 ng/g results in a mass estimate of 1.15 kg in Lake Spokane sediments. Compared to the 0.0008 kg calculated above for the Spokane River, it is apparent that the majority of PCBs in bedded sediments in the study area are contained in Lake Spokane. It is noted that this estimate considers only the upper 10 cm of sediments, representing the maximum depth at which PCBs can reasonably be assumed to be available for release to the lake. A much larger mass of PCBs is present deeper in the lake sediment bed that is assumed for this assessment to be isolated from further release into the environment.

### Industrial equipment

The primary sources of legacy PCBs contained in industrial equipment correspond to transformers and large (over three pounds) capacitors. Information on the presence and PCB content of these sources was provided by Avista Utilities, who is responsible for the generation and transmission of electricity in the Spokane region.

Avista operates x[[3]](#footnote-3) transformers in the region, with an average PCB content of x3, corresponding to total PCB mas of x3. Avista no longer uses capacitors over three pounds, so the estimated PCB content for this source category is zero.

## Ongoing Sources

Despite the ban on the intentional production of PCBs instituted in 1979, PCBs still continue to be inadvertently produced in the chemical synthesis of many commercial products. EPA promulgated a rule under the Toxics Substance Control Act for inadvertent generation of PCBs that are not in closed or controlled manufacturing processes. The concentration of inadvertently generated PCBs in products must have an annual average of <25 ppm, with a maximum of 50 ppm. LimnoTech (2015) divided ongoing sources into categories of:

* Pigments in printed materials/fabrics: Newsprint, commercial packaging, colored clothing
* Paints: Architectural paint, road paint
* Other: Many products, including motor oil and agricultural chemicals

Studies have been conducted testing the levels of PCBs in a wide range of products (e.g. City of Spokane, 2015; Hu and Hornbuckle, 2010.) The number of products tested, however, in conjunction with a lack of information on the quantity of goods being imported into the watershed by category, prevent calculation of category-specific magnitude estimates. Work conducted as part of the Ecology and DOH (2015) PCB Chemical Action Plan provides a template for estimating of the overall magnitude of all inadvertent sources being imported into the watershed:

The US market consumes approximately 20% of global organic pigments (Guo et al. 2014). Washington is approximately 2% of the US population, which leads to an estimate for Washington’s share of PCB-11 from yellow pigment of 0.02 and 31 kg per year. This is the amount of PCB-11 in products, with an unknown amount entering the environment. The Color Pigments Manufacturers Association (CPMA) estimated that the total annual amount of these pigments (phthalocyanine and diarylide) imported or manufactured in the US is about 90 million lbs (41,000 metric tons). They further estimated inadvertently generated PCBs in these pigments with an upper bound of 1.1 tons per year and a more reasonable estimate of 1000 lbs per year (CPMA 2010). Using the lower annual estimate of 1000 lbs (450 kb), leads to an estimate of 9 kg per year in Washington, that is within the range of the estimate above.

Scaling the above estimate to the population of the Spokane watershed leads to a loading estimate for Spokane of 0.86 kg/yr.

## Non-Local Environmental Sources

PCBs also enter the Spokane watershed study area (presently defined as having an upstream boundary at Lake Coeur d’Alene) via non-local environmental sources. LimnoTech (2015) divided non-local environmental sources into categories of:

* Atmospheric: Atmospheric sources originating outside of the watershed
* Up-watershed: Entering the river from Lake Coeur d’Alene.

### Atmospheric

No definitive information exists on the specific amount of PCBs delivered to the Spokane area from atmospheric sources, regardless of origin. Era-Miller (2011) in a literature review of toxics atmospheric deposition in Eastern Washington State, found no data available for atmospheric PCBs in eastern Washington. The closest relevant reference site with atmospheric PCB data was from Summerland, British Columbia, with a measured annual PCB concentration of 4.4 ng/PAS (Passive Air Sampler). Era-Miller’s review showed a range of reported significance of non-local sources compared to local sources. A model PCBs in the Willamette River Basin suggested that PCBs came primarily from non-local sources and local soil sources, while a second source in that review (Simonich, cited as personal communication) suggested that the contribution of trans-Pacific sources to PCB, PBDE, and PCDD/F deposition in Eastern Washington was less than 2%. Ecology’s Environmental Assessment Program is currently undertaking a study that will provide information on this source category.

### Up-Watershed

An estimate of PCB loading to the Spokane River from Lake Coeur d’Alene was calculated by multiplying the annual average flow out of the lake (175 m3/sec) times the average PCB concentration measured by the SRRTTF during confidence testing and synoptic surveys (17 pg/l). It is recognized that the PCB concentration data are dominated by summer low-flow measurements, although no significant difference in concentrations were observed between seasons. The resulting load estimate is 0.0959 kg/year.

# Magnitude of Delivery Mechanisms of PCBs to the Spokane River

The mechanisms that can deliver PCBs to the Spokane River study area were defined by LimnoTech (2015) as:

* Transport of PCBs from upstream sources through Lake Coeur d’Alene
* Atmospheric deposition directly to water bodies
* Groundwater loading
* MS4 stormwater/combined sewer overflows (CSOs)
* Tributaries
* Discharge from municipal and industrial wastewater treatment plants
* Discharge of waste water and stocking of fish from fish hatcheries
* Diffusion or resuspension of PCBs from bedded sediments in the Spokane River and Lake Spokane

Consistent with the assumptions of Ecology (2011), direct stormwater runoff direct draining to the Spokane River from areas other than the City of Spokane’s MS4 system is assumed to be small. Stormwater runoff drainage to tributaries will be reflected in the tributary loading estimates for Latah Creek and the Little Spokane River.

The mass loading rate for PCBs estimated in each source category is provided in Table 2.

|  |  |
| --- | --- |
| **Source Category** | **PCB Loading Rate**  |
| Upstream sources | 263 mg/day; 0.096 kg/year |
| Atmospheric deposition to surface water | <0 |
| Groundwater loading | 148.7 mg/day; 0.054 kg/year |
| MS4 stormwater/CSOs | 38 mg/day; 0.014 kg/year |
| Tributaries | 227 mg/day; 0.083 kg/year |
| Municipal and industrial WWTPs | 299 mg/day; 0.11 kg/yr |
| Fish hatcheries | Unknown[[4]](#footnote-4) |
| Bottom sediments | 1.22 mg/day; 0.00044 kg/yr |

**Table 2. PCB Loading Rates Estimated for each Delivery Mechanism**

The remainder of this section describes how each of these estimates was determined.

## Transport of PCBs from Upstream Sources through Lake Coeur d’Alene

Transport of PCBs from upstream sources through Lake Coeur d’Alene was estimated in the previous section as 0.096 kg/year.

## Atmospheric Deposition Directly to Water Bodies

PCBs can be delivered directly to surface waters from atmospheric sources via three mechanisms: wet deposition, dry deposition, and gas deposition. Wet deposition consists of PCBs contained in precipitation. Dry deposition consists of PCBs attached to airborne particulate matter that settle onto the surface water. Gas deposition occurs as a transfer across the air-water interface when atmospheric gas-phase PCB concentrations exceed the equivalent dissolved phase PCB concentrations in the water column. Research (Miller et al, 2001) has shown that the primary mechanism for atmospheric PCBs to enter surface waters is through gas-phase exchange, so the calculations that follow focus solely on gas deposition as the dominant component of atmospheric PCB loading.

The magnitude of gas deposition is determined by three primary factors, the atmospheric gas phase PCB concentration, the water column PCB concentration and the mass transfer coefficients that control the rate at which PCB concentrations pass through the air-water interface. Screening-level calculations of gas phase PCB exchange for Spokane focused on Lake Spokane itself, which provides the large majority of overall surface area. Gas-phase atmospheric PCB concentrations were estimated from a population-based regression of Venier and Hites (2010) as 0.121 ng/m3. The water column PCB concentration was specified as 163.2 pg/L, based upon the average concentration observed at Nine Mile Dam during the 2014 synoptic survey. Representative mass transfer coefficients were taken from Chapra (1996). These values lead to a net movement of PCBs out of the water column and into the atmosphere, i.e. no net loading of PCBs from the atmosphere to the water column.

## MS4 Stormwater Runoff/Combined Sewer Overflows (CSOs)

Sampling of the City of Spokane stormwater/CSO discharges for PCBs first occurred in 2007 by Ecology and Parsons (Parsons, 2007). From 2012 through 2014, the City of Spokane monitored three MS4 stormwater basins (Cochran, Union, Washington) and two CSO basins (CSO34 and CSO06) on a near-monthly basis. Hobbs (2015) reviewed the available data and calculated mass loading of PCBs to the river for individual storms. Donovan (2015) generated annual loading estimates for MS4 and CSO sources, based upon:

* Annual rainfall of 18 inches
* Site-specific regression of discharge from the Cochran basin to rainfall
* Ratio of impervious area in other basins to impervious area in Cochran basin
* Average stormwater PCB concentration observed in Cochran basin to represent all basins except Union and Washington
* Average stormwater PCB concentration observed in Union basin
* Average stormwater PCB concentration observed in Washington basin
* 2005 actual CSO flow
* Average CSO 6 PCB concentration to represent CSO 6
* Average CSO 34 PCB concentration to represent CSO 34
* AVG of CSO 34 and CSO 6 PCB concentration to represent all other CSOs

The above information resulted in an annual loading rate of 29.9 mg/day (0.01 kg/year) for MS4 stormwater, 7.6 mg/day (0.028 kg/year) for CSO, and a total of 37.6 mg/day (0.014 kg/year).

## Tributaries

Two tributaries enter the Spokane River within the study area, Latah Creek and the Little Spokane River. Each are discussed below.

### Latah Creek

 An annual PCB loading estimate for Latah Creek was obtained using long-term average observed creek flow (6.5 m3/sec) and the average concentration observed during the 2014 SRRTTF synoptic survey (383 pg/l), resulting in an annual loading estimate of 0.078 kg/yr (215.3 mg/day). This loading estimate is heavily influenced by a single observed concentration measurement of 2444 pg/l. Deleting that one potentially unrepresentative sample from the calculation results in an average concentration of 89 pg/l and a loading estimate of 0.018 kg/yr (50 mg/day). Taking a midpoint of these two values results in an estimate of 0.048 kg/yr.

### Little Spokane River

The PCB loading estimate for the Little Spokane was based on the assessment by Serdar et al (2011), which used the average Little Spokane PCB concentration data from 2003-2004 (199 pg/l) and historic flows at the USGS Gage at Dartford (5.6 m3/sec). The estimated average total PCB load in the Little Spokane River was 97 mg/day (0.035 kg/year). Data collected in 2013-2014 reported by Friese and Coots (2016) suggest much lower river concentrations, although blank contamination issues prevented them from providing a quantitative estimate of concentration.

## Discharge from Municipal and Industrial Wastewater Treatment Plants

Loading estimates for municipal and industrial wastewater treatment plants were calculated from effluent data collected by the plants, supplemented with data obtained during the SRRTTF synoptic surveys. Results are summarized in Table 3. These loading estimates have some uncertainty due to different blank correction methods being applied between the SRRTTF and the assessments conducted by the dischargers themselves. This discrepancy is best highlighted by the data for the Spokane County Regional Water Reclamation Facility. The average effluent concentration reported across the 2014-2015 SRRTTF synoptic surveys assessments was 361 pg/l, while the average effluent concentration reported in the 2015 Annual Toxics Management Report (which exclude congener values <10x the sample blank) was 30 pg/l (Brown and Caldwell, 2015). Entries in Table 3 are footnoted to indicate which values came from the synoptic surveys versus discharger monitoring. The range in total loading rate is 282 – 315 mg/day, with a midpoint value of 299 mg/day.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **PCB Concentration (pg/l)** | **Flow (cfs)** | **Load (mg/day)** |
| Coeur d’Alene | 532.5[[5]](#footnote-5) | 5.355 | 6.975 |
| Post Falls | 163[[6]](#footnote-6) - 2135 | 3.89 | 1.56 - 2.05 |
| HARSB | -[[7]](#footnote-7) | -5 | -5 |
| Liberty Lake | 218.75 | 0.65 | 1.125 |
| Kaiser | 2231.55 - 3264.2 | 13.25 -18.46 | 1016-1055 |
| Inland Empire Paper | 31805 | 10.85 | 84.35 |
| Spokane County | 306 - 3615 |  | 0.876 - 10.45 |
| City of Spokane | 7296 – 9755 | 44.15 – 48.96 | 87.26 – 1055 |
| **Total** |  |  | **2826 – 3155** |

**Table 3. Annual PCB Loading Rates from Municipal and Industrial WWTPs**

## Discharge of Waste Water and Stocking of Fish from Fish Hatcheries

PCB contributions to Spokane River from fish hatcheries can arise from the stocking of PCB-contaminated fish and discharge of effluent from the Washington Department of Fish and Wildlife’s Spokane Fish Hatchery to the Little Spokane River. Approximately 170,000 rainbow trout are planted annually to Lake Spokane and the Spokane River. The fish raised are in two different hatcheries, Troutlodge in Soap Lake, and the Spokane Fish Hatchery. Serdar et al (2006) found PCB concentrations of 6.5 ug/kg in hatchery trout from the Spokane Fish Hatchery and 14.4 ug/kg in fish fillets from the Troutlodge facility. Fish feed from the Spokane hatchery was analyzed by Serdar et al (2006) with a result of 16.4 ug/kg. No quantitative estimate exists for PCB loading from discharge of waste water and stocking of fish from these hatcheries, although Ecology (2016) is conducting a study to provide these estimates.

## Diffusion or Resuspension of PCBs from Bedded Sediments in the Spokane River and Lake Spokane

No site-specific data were available to define the magnitude of pore water diffusion and/or resuspension of PCBs into the study areas from bed sediments. Given that the calculations above show that the mass of PCB in lake sediments is more than 100x greater than river sediments, it can be reasonably assumed that overall flux from bedded sediments is dominated by flux from lake sediments. The magnitude of pore water diffusion from lake bed sediments was estimated based on a combination of physical-chemical properties taken from the development of the MICHTOX Lake Michigan Mass Balance Project (USEPA, 2006; Endicott, 2005; and Endicott et al., 2005) with study area-specific measurements of sediment PCB concentrations. The resulting gross PCB diffusive flux from the lake sediments was estimated at 1.22 mg/day.

Lacking site-specific data on the magnitude of sediment resuspension for bed sediment PCBs, it can be reasonably assumed that this process is much smaller than sediment diffusion, given that: 1) this is a lake, rather than a river; 2) PCB concentrations are greatest in the deeper areas of Lake Spokane where resuspension is least likely; and 3) much of the re-suspended sediment PCB will re-deposit shortly after resuspension events.

# Magnitude of Intermediate Transport Pathways

It is recognized that there are a number of intermediate pathways by which the sources of PCBs get transported to the delivery mechanisms described above. LimnoTech (2015) divided these pathways under the categories of:

* Mobilization in the watershed
* Volatilization to the atmosphere
* Delivery to sewer infrastructure
* Contribution to groundwater

## Mobilization in the Watershed

Many of the sources of PCBs are contained within products of some kind and must first undergo a mobilization step to allow them to be transported through the watershed and/or to the Spokane River. Watershed mobilization pathways defined in LimnoTech (2015) consist of:

* Demolition from fixed building sources
* Transfer of non-fixed building sources to recycling facilities
* Spills/leaks of PCBs contained in industrial sources
* Littering/recycling of PCBs in consumer products
* Deposition and gas transfer of atmospheric sources
* Application of PCB-containing materials to watershed

### Fixed Building Sources: Demolition/Volatilization

Little information is available on the mobilization of PCBs from fixed building sources, with many studies assuming that volatilization is the dominant mobilization method (e.g. Shanahan et al, 2015). Ecology (2011) notes, however, that volatilized PCBs may quickly attach to other media include adjoining materials, or dust and films. Weathering of caulk through fragmentation and abrasion may also release PCBs directly in particle form. For these reasons, mobilization from fixed building sources has been combined into a lumped demolition/ volatilization category. Robson et al. (2010) calculated a long-term gross mean regional sealant PCB loss rate of 9% over 50 years of exposure, i.e. 0.018/yr. Combining this loss rate of with the total PCB mass estimated above of 2969 kg results in a release rate of 53.4 kg/yr.

### Transfer of Non-Fixed Building Sources to Recycling Facilities

No site-specific data are available describing the transfer of non-fixed building sources to recycling facilities. Assumptions used for the Puget Sound Source Assessment (Ecology, 2011) were applied here. They estimated a release rate from small capacitors of approximately 1 to 1,000 kg/yr, with a mid-point of is 500 kg. Scaling that estimate by population to the Spokane watershed results in range of 0.1 to 95 kg/yr, with a mid-point of 48 kg/yr.

### Spills/Leaks of PCBs Contained in Industrial Sources

Avista maintains all large transformers in the watershed in controlled areas, and implements immediate remediation activities in the event of leakage that prevents the release of PCBs to the outside environment (Bryce Robbert, personal communication). As such, the release rate of PCBs from industrial sources is essentially zero.

### Littering/Recycling of PCBs in Consumer Products

No quantitative information is available for this pathway. An upper bound estimate can be made assuming that all inadvertently produced PCBs imported into the watershed over the course of the year become available through this pathway. As described above in the Sources section, this results in a upper bound release rate estimate for Spokane of 0.86 kg/yr.

### Deposition and Gas Transfer of Atmospheric Sources

As discussed in the Ongoing Sources section above, no definitive information exists on the specific amount of PCBs delivered to the Spokane area from atmospheric sources. Ecology is currently undertaking a PCB atmospheric deposition study in Spokane to address this need.

### Application of PCB-Containing Materials to Watershed

LimnoTech (2015) identified that produced PCBs can be directly applied to the watershed via hydro-seed, de-icer, herbicides and pesticides, and biosolids or fertilizer applications. No quantitative data are available to estimate the overall magnitude of this pathway, although the application of biosolids may be an important component. Shanahan et al (2015) estimated the average concentration of PCBs in municipal sewage sludge at 1.0 mg/kg dry weight, based on the work of Rodenburg and Meng (2007) and Norström et al (2010). An upper bound estimate for PCB transport via sludge application can be made by assuming that all PCBs removed from municipal influents are land applied as sludge. As described below, the influent PCB load to municipal plants was estimated at 2108 mg/day. Table 3 showed that municipal plants discharge approximately 111 mg/day, resulting in an upper bound estimate for sludge application of 2000 mg/day (0.73 kg/year).

## Mobilization to the Atmosphere

Numerous sources contribute to local atmospheric concentrations of PCBs via volatilization, i.e. conversion into a gas phase. Atmospheric mobilization pathways defined in LimnoTech (2015) consist of:

* Volatilization directly from previously defined source categories.
* Combustion sources
* Volatilization of PCBs from wastewater treatment sludge
* Transport of PCBs generated outside of the watershed

### Volatilization Directly from Previously Defined Source Categories

Shanahan et al (2015) showed that volatilization from contaminated surface soils was the dominant source of atmospheric PCB load in the Chicago area. They estimated that a soil PCB mass of 2,200 kg resulted in a volatilization load of 64 kg/yr. Scaling their results to the mass load of 5,500 kg estimated above for the Spokane watershed results in a volatilization load of 160 kg/yr.

### Combustion Sources

Potential combustion sources include internal combustion engines, incinerators, used oil burning and residential burning. Of these, quantitative estimates were found in Ecology and DOH (2015) for residential trash burning and the Spokane Waste to Energy Plant. According to the most recent NEI for 2008, there were 199 kg of PCBs released to the air in Washington State from residential waste burning. Scaling this estimate by population results in a Spokane watershed estimate of 16.9 kg/yr. Ecology and DOH (2015), citing the Spokane Regional Clean Air Agency, reported about 1 lb of PCB emitted from the Spokane Waste to Energy Plant in 2011 (0.45 kg/yr). The upcoming Ecology PCB atmospheric deposition study in Spokane will provide more information on the significance of this source.

### Volatilization of PCBs from Wastewater Treatment Sludge

Shanahan et al (2015) estimated that volatilization of wastewater treatment sludge was the second largest source of PCB release in the Chicago area. No site-specific data exists on the amount of PCBs volatilized from sludge in Spoknae, although an estimate can be obtained from the previously calculated amount upper bound estimate of PCB sludge generation of 2000 mg/day (0.73 kg/year), combined with the determination of Shanahan et al (2015) that 2.5% of the PCB content of sludge is lost to volatilization, to estimate a volatilization load of 50 mg/day (0.018 kg/year).

### Transport of PCBs Generated Outside of the Watershed

This category is the same as the non-local atmospheric sources category discussed above in the section on Ongoing Sources. As discussed there, little definitive information exists on the specific amount of PCBs delivered to the Spokane area from atmospheric sources. Ecology’s Environmental Assessment Program is currently undertaking a study that will provide information on this source category.

# Delivery to Sewer Infrastructure

The Spokane watershed contains a range of sewer infrastructure capable of delivering PCBs, either directly or indirectly, to the river. This infrastructure can be broadly divided into categories of stormwater and wastewater.

## Stormwater

No quantitative estimate exists defining the quantity of PCBs being delivered to the stormwater system. A lower bound estimate of loading to the City of Spokane’s MS4 system can be obtained from the stormwater loading estimate provided above of 29.9 mg/day (0.01 kg/year). No information exists to estimate PCB loading to non-discharging stormwater systems.

## Wastewater

An estimate of PCBs delivered to municipal wastewater systems can be obtained from observed influent PCB concentrations. Review of influent PCB data provided by the City of Spokane, Spokane County, and Post Falls show an average influent concentration of 13,000 pg/l. Multiplying this influent concentration by cumulative municipal discharge flow results in a loading rate of 2107.8 mg/day (0.77 kg/yr).

# Contribution to Groundwater

The final intermediate transport pathway defined in LimnoTech (2015) is contribution to groundwater, divided into categories of:

* Legacy contamination
* Landfill disposal of PCB-containing products
* Leaking well pumps
* Private septic systems
* UIC wells (referred to as Dry Wells in LimnoTech, 2015)

## Legacy contamination

The Magnitude of Sources section above concluded that insufficient data exist to estimate the total mass of legacy subsurface PCB contamination; correspondingly, insufficient data are available to estimate the rate at which this legacy subsurface contamination contributes to groundwater. A lower bound estimate can be gained from the groundwater loading calculation presented above in the Magnitude of Delivery Mechanisms section, which estimated the groundwater loading in the river section directly below Mirabeau Park at 148.7 mg/day (0.054 kg/year).

## Landfill disposal of PCB-containing products

Similarly, no data were found describing groundwater PCB loading from landfills. Modern landfills are designed and operated to prevent any adverse effects to groundwater. Older landfills still exist in the watershed that were not designed or operated to modern standards. However, many of these older landfills suspected of contributing toxic materials to local groundwater have been named as National Priorities List (NPL) sites under the Comprehensive Environmental Response, Compensation and Liability Act, and have undergone remedial actions to address potential groundwater contamination (SCS, Engineers, 2015.)

## Leaking well pumps

The Wisconsin Department of Natural Resources and Division of Health (WDNR, 2008) determined that certain submersible pumps used to draw water from wells may leak PCBs into ground water. The dielectric fluid in capacitors used in certain pump motors manufactured before 1979 was made of PCBs, with each capacitor containing up to five ounces of PCBs. These PCBs can gradually during normal wear-and-tear. No quantitative information was available describing the rate of leakage.

## Private septic systems

There are over 45,000 private septic systems in Spokane County, with 200 to 300 new systems are added annually and 50 to 150 systems removed due to connection to sewer or abandonment. At least 10,000 systems are likely located over the aquifer contributing to the Spokane River (S. Phillips, personal communication). Given observed PCB concentrations greater than 10,000 pg/l in municipal wastewater influent as discussed above, it is reasonable to assume that similarly high PCB concentrations are delivered to septic tanks. No quantitative information exists defining the rate at which these PCBs may be delivered to the groundwater contributing to the Spokane River.

## UIC wells

Underground Injection Control (UIC) wells are manmade structures used to discharge fluids into the subsurface. Examples of UIC wells include dry wells, infiltration trenches with perforated pipe, and any structure deeper than the widest surface dimension (<http://www.ecy.wa.gov/PROgrams/wq/grndwtr/uic/index.html>). Marti and Maggi (2015) reviewed the abundance and use of UIC wells in Washington. Ecology’s Underground Injection Control (UIC) Program protects groundwater quality by regulating the disposal of fluids through UIC wells. Approximately 14,000 UICs have been registered in Spokane County. These wells receive stormwater runoff from paved areas, such as parking lots, streets, residential subdivisions, building roofs, and highways. Marti and Maggi (2015) note that the potential for groundwater contamination from UICs depends upon the UIC wells’ construction and location, the type and quality of fluids being injected, and the geographic and subsurface setting in which the injection occurs. UICs used along roads and parking areas are not typically considered a high threat to groundwater if they have been built to meet the requirements of the Guidance for UIC Wells that Manage Stormwater (Ecology, 2006). UICs constructed before 2006 and used to manage stormwater are required to have a well assessment to determine if they pose a risk to groundwater. A well assessment evaluates the land use around the UIC, which may affect the quality of the discharge, and whether the UIC is located in a groundwater protection area. If a UIC well is considered a high threat to groundwater, the assessment may also include information on the local geology and depth to groundwater in relation to the UIC well. Beyond the control measures discussed immediately above, no quantitative information exists on the rate at which PCBs may be delivered to Spokane area groundwater from UIC wells.

# References

Andersson, M., R. Ottesen, and I. Volden. Building materials as a source of PCB pollution inBergen, Norway. Sci Total Environ 325:139–44.

ASTDR (2000) Toxicological Profile for Polychlorinated Biphenyls (PCBs), Agency for Toxic Substances and Disease Registry, US Department of Health and Human Services. 948 pages, <http://www.atsdr.cdc.gov/toxprofiles/tp17-p.pdf>.

Brown and Caldwell, 2015. 2015 Annual Toxics Management Report, Spokane County Regional Water Reclamation Facility NPDES Permit WA-0093317.

Chapra, S. C., 1990. Surface Water Quality Modeling, Edition 1. McGraw-Hill Higher Education. New York.

City of Spokane, 2015. PCBs in Municipal Products. City of Spokane Wastewater Management Department. Ecology Municipal Stormwater Grants of Regional or Statewide Significance Grant No. G1400545. Revised July 21, 2015.

Donovan, J. 2015. Excel Spreadsheet “City of Spokane Stormwater Flow and PCB load Estimate JeffD 11-12-2015.xlsx” transmitted in November 19, 2015 email “RE: City of Spokane Stormwater Flow”

Ecology and DOH, 2015. PCB Chemical Action Plan. Prepared by Washington State Department of Ecology and Washington State Department of Health, Publication no. 15-07-002. February 2015.

Ecology, 2016. Quality Assurance Project Plan Spokane and Troutlodge Fish Hatchery PCB Evaluation. Prepared by Washington State Department of Ecology. Publication No. 16-03-104. March 2016.

Ecology, 2015. Periodic Review, Spokane River Upriver Dam and Donkey Island PCB Sediment Site. Prepared by Washington State Department of Ecology, Eastern Regional Office Toxics Cleanup Program. December, 2015.

Ecology, 2006. Guidance for UIC Wells that Manage Stormwater. Watershed Management Section. WA Dept of Ecology, Pub #05-10-067.

Endicott, D.D., 2005, 2002 Lake Michigan Mass Balance Project: modeling total polychlorinated biphenyls using the MICHTOX model. Part 2 in Rossmann, R. (ed.), MICHTOX: A Mass Balance and Bioaccumulation Model for Toxic Chemicals in Lake Michigan. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Laboratory, Mid-Continent Ecology Division, Large Lakes and Rivers Forecasting Research Branch, Large Lakes Research Station, Grosse Ile, Michigan. EPA/600/R-05/158, 140 pp.

Endicott, D.D., W.L. Richardson, and D.J. Kandt, 2005. 1992 MICHTOX: A Mass Balance and Bioaccumulation Model for Toxic Chemicals in Lake Michigan. Part 1 in Rossmann, R. (ed.), MICHTOX: A Mass Balance and Bioaccumulation Model for Toxic Chemicals in Lake Michigan. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Laboratory, Mid-Continent Ecology Division, Large Lakes and Rivers Forecasting Research Branch, Large Lakes Research Station, Grosse Ile, Michigan. EPA/600/R-05/158, 140 pp.EPA, 1982. 40 CFR Part 761 Polychlorinated Biphenyls (PCBs); Use in Electrical Equipment, Proposed Rule. Federal Register 47 (78), April 22.

EPA, 1987. Locating and Estimating Air Emissions from Sources of Polychlorinated Biphenyls (PCB). U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle, North Carolina. 74 pages. EPA-450/4-84-007n.

EPA, 1998. Implementing the Binational Toxics Strategy, Polychlorinated Biphenyls (PCBs) Workgroup: Background Information on PCB Sources and Regulations. Proceedings of he 1998 Stakeholder Forum.

Era-Miller, B. 2014. Technical Memo: Spokane River Toxics Sampling 2012-2013, Surface Water, CLAM, and Sediment Trap Results. Prepared for Elaine Adriane Borgias, May 30, 2014.

Era-Miller, B. 2011. Memo: Toxics Atmospheric Deposition in Eastern Washington State - Literature Review. Prepared for Elaine Snouwaert, November 15, 2011. Project code 10-124. 29 p.

Friese, M. and R. Coots. 2016. Little Spokane River PCBs, Screening Survey of Water, Sediment, and Fish Tissue. Washington State Department of Ecology, Environmental Assessment Program. Publication No. 16-03-001. March 2016.

Guo, J., P. Praipipat, and L. A. Rodenburg. 2013. PCBs in Pigments, Inks, and Dyes: Documenting the Problem. 17th Annual Green Chemistry & Engineering Conference. June 18-20, 2013.

Hobbs, W. 2015. Spokane Stormwater. Memorandum to Adriane Borgias, Water Quality Program, Ecology. October 15, 2015.

Hope, B. K. 2008. A Model for the Presence of Polychlorinated Biphenyls (PCBs) in the Willamette River Basin (Oregon). Environ. Sci. Technol., 42 (16), pp 5998–6006.

Hu, D., and K. C. Hornbuckle. 2010. Inadvertent Polychlorinated Biphenyls in Commercial Paint Pigments. Environ. Sci. Technol. 2010, 44, 2822–2827.

LimnoTech, 2015. Sources and Pathways of PCBs in the Spokane River Watershed. Prepared for the Spokane River Regional Toxics Task Force. Spokane, WA.

LimnoTech, 2013. Initial Conceptual Models of PCBs and Dioxins in the Spokane River Watershed. Prepared for the Spokane River Regional Toxics Task Force. Spokane, WA. November 14, 2013.

Marti, P., and M. Maggi. 2015. Assessment of PCBs in Spokane River Groundwater. Memo to Adriane Borgias. Washington State Department of Ecology, Environmental Assessment Program. September 16, 2015.

Meijer, S. N., W. A. Ockenden, A. Sweetman, K. Breivik,; J. O. Grimalt, and K. C. Jones. 2003. Global distribution and budget of PCBs and HCB in background surface soils: Implications or sources and environmental processes. Environ. Sci. Technol., 37 (4), 667−672.

Miller, S.M., M.L. Green, J. V. DePinto, and K.C. Hornbuckle, 2001. Results from the Lake Michigan Mass Balance Study: Concentrations and Fluxes of Atmospheric Polychlorinated Biphenyls and trans-Nonachlor. Environmental Science and Technology. 35: 278-285.

Norström, K., G. Czub, M. S. McLachlan, D. Hu, P. S. Thorne, and K. C. Hornbuckle. 2010. External exposure and bioaccumulation of PCBs in humans living in a contaminated urban environment. Environ. Int., 36 (8), 855−861.

Panero, M., Boheme, S., and Muñoz, G. Pollution Prevention and Management Strategies for Polychlorinated Biphenyls in the New York/New Jersey Harbor. February 2005. New York Academy of Sciences, New York, NY. Available at: <http://www.nyas.org/WhatWeDo/Harbor.aspx>

Robson M, L Melymuk, S. A. Csiszar, A. Giang, M L. Diamond, and P.A. Helm. 2010. Continuing sources of PCBs: The significance of building sealants. Environment International 36: 506-513.

Rodenburg, L. A.; Meng, Q. Y. 2007. Source Apportionment of Polychlorinated Biphenyls in Chicago Air from 1996 to 2007. Environ. Sci. Technol. 2013, 47 (8), 3774−3780.

San Francisco Estuary Institute, 2010. A BMP Tool Box for Reducing Polychlorinated Biphenyls (PCBs) and Mercury (Hg) in Municipal Stormwater. San Francisco Estuary Institute, Oakland CA.

SCS Engineers. 2015. Spokane County Solid Waste and Moderate Risk Waste Management Plan. Prepared for Spokane County. January 2015. File No. 01214128.00

Serdar, D., K. Kinney, M. Mandjikov, and D. Montgomery, 2006. Persistent Organic Pollutants in Feed and Rainbow Trout from Selected Trout Hatcheries. Washington State Department of Ecology. Publication No. 06-03-017.

Serdar, D., B. Lubliner, A. Johnson, and D. Norton. 2011. Spokane River PCB Source Assessment, 2003-2007. Prepared by Toxics Studies Unit, Environmental Assessment Program, Washington State Department of Ecology. Publication No. 11-03-013. April, 2011.

Shanahan, C.E., S. N. Spak, A. Martinez, and K. C. Hornbuckle. 2015. Inventory of PCBs in Chicago and Opportunities for Reduction in Airborne Emissions and Human Exposure. Environ. Sci. Technol., 2015, 49 (23), pp 13878–13888.

Shen, L., F. Wania, Y. D. Lei, C. Teixeira, D. C.G. Muir, and H. Xiao. 2006. Polychlorinated Biphenyls and Polybrominated Diphenyl Ethers in the North American Atmosphere. Environmental Pollution 144:434-444.

U.S. Army, 2001. Fact Sheets and Information Papers: Disposal of PCB Capacitors from Light Ballasts. U.S. Army, Center for Health Promotion and Preventive Medicine. Aberdeen, MD.

USEPA, 2006. Results of the Lake Michigan Mass Balance Project: Polychlorinated Biphenyls Modeling Report. Rossmann, R. (Ed.) United States Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Mid-Continent Ecology Division-Duluth, Large Lakes and Rivers Forecasting Research Branch, Large Lakes Research Station, Grosse Ile, Michigan. EPA-600/R-04/167, 579 pp.

Venier, M. and Hites, R. A., 2010.Regression Model of Partial Pressures of PCBs, PAHs, and Organochlorine Pesticides in the Great Lakes' Atmosphere, Environmental Science & Technology, 44 (2), 618–623.

Wisconsin Dept. of Natural Resources, 2008. Submersible Wells Pumps and Water Contamination. WI Dept. of Natural Resources, Pub #2008-05-02.

1. Awaiting data from Avista. [↑](#footnote-ref-1)
2. Ecology’s Environmental Assessment Program is undertaking a study that will provide information on this source. [↑](#footnote-ref-2)
3. Awaiting data from Avista. [↑](#footnote-ref-3)
4. Ecology’s Environmental Assessment Program is currently undertaking a study that will provide information on this source category. [↑](#footnote-ref-4)
5. Data from synoptic surveys [↑](#footnote-ref-5)
6. Data from discharger monitoring [↑](#footnote-ref-6)
7. Awaiting data from HARSB [↑](#footnote-ref-7)